International Journal of Electronics,
Communication & Instrumentation Engineering
Research and Development (IJECIERD)
ISSN(P): 2249-684X; ISSN(E): 2249-7951
Vol. 4, Issue 3, Jun 2014, 97-104

LDPC ENCODER FOR OFDM BASED COGNITIVE RADIO

N. MUGESH[1], J. ROBERT THEIVADAS[2] & S. K. PADMANABHAN[3]

[1]M.E.VLSI Design, Department of ECE, Anand Institute of Higher Technology, Chennai, Tamil Nadu, India

[2]Assistant Professor, Department of ECE, Anand Institute of Higher Technology, Chennai, Tamil Nadu, India

[3]Associate Professor, Department of ECE, Jeppiaar Engineering College, Chennai, Tamil Nadu, India

ABSTRACT

The objective of this paper is to analyse the working of Low density parity check code scheme (LDPC) for precoded OFDM method. The precoded OFDM overcomes the dearth of availability of spectrum by means of look ahead value insertion at the transmitter so that the interference of the primary channel is eliminated. This aid in transmitting data through the spectrum holes which is the main objective of cognitive radio. The method though prevents the interference from secondary system, the effect of noise which is added by the channel has to be reduced in order to improve the BER.

KEYWORDS: Cognitive Radio, OFDM, LDPC, Precoding, Channel State Information

I. INTRODUCTION

A cognitive radio is a system which utilises the spectrum efficiently by means of sensing the current state of the spectrum and then adapting its processes with accordance to that of the channel. The main objective of cognitive radio is to maximize the utility by means of sharing the channel of a primary system with that of the secondary system [1]. The spectrum holes are found out and the data are transmitted through them. When there is impossibility of a spectrum hole two systems have to share the same spectrum. The spectrum hole is the unused frequency band which is allocated to a primary user [2]. Thus while sharing there is serious drawback of interference caused by each system to one another. The cognitive principle is developed on the basis that the secondary transmitter does not pose any problem at the primary receiver. This requires the secondary transmitter to know the message [3] and both the primary and secondary transmitter to know exactly their all the local channel. The first condition may have difficulties if the systems follow non cooperative policies [4]. There may be some scenarios where the primary would have no idea of the secondary system being exist. Hence in this paper we propose a method by which the secondary transmitter precodes the data in order to eliminate the interference at the primary receiver. This is different from that of the VFDM system proposed in [5], [6], [7] in way that the proposed system in this paper is developed over the existing OFDM system.

II. COGNITIVE INTERFERENCE CHANNEL

Consider a primary and secondary system which shares a common cognitive channel as shown in the figure below.

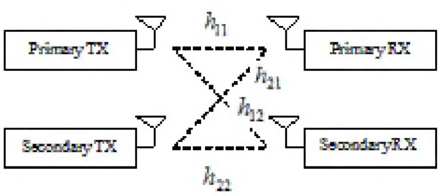

Figure 1: Cognitive Interference Channel

The data from the transmitters are propagated to their respective receivers by means of the direct channel h_{11} and h_{22} respectively. The primary system message is subjected to interference due message from the secondary system through the indirect channel h_{21} . Similarly the primary causes interference to the secondary system through the indirect channel h_{12} . The message received at the primary receiver can be can be modelled mathematically as given below

$$\Re_1 = H(h_{11})x_1 + H(h_{21})x_2 + n_1 \tag{1}$$

And the message at the secondary receiver is obtained as

$$\Re_2 = H(h_{22})x_2 + H(h_{12})x_1 + n_2 \tag{2}$$

Where $\Re_1$ and $\Re_2$ are the message received x_1 and x_2 being the transmitted message. The messages x_1 and x_2 are OFDM data obtained by taking Inverse Fast Fourier Transform their message symbols s_1 and s_2 along with a cyclic prefix addition given by a matrix C

$$x_1 = CF^{-1}(s_1) \tag{3}$$

And

$$x_2 = CF^{-1}(s_2) \tag{4}$$

In the equation (1) the notation $H(h_{ij})$ represents the channel between the i_{th} transmitter and the j_{th} receiver which modelled from the channel filter tap weights [8] as a Toeplitz matrix of order $(L + L_p) \times (L + L_p + L_c - 1)$

$$H(h_{ij}) = \begin{bmatrix} h_1^{ij} & \dots & h_{L_c}^{ij} & 0 & \dots & \dots & \dots & 0 \\ 0 & h_1^{ij} & \dots & h_{L_c}^{ij} & 0 & \dots & \dots & 0 \\ \vdots & & \ddots & & \ddots & & & \vdots \\ \vdots & \dots & 0 & h_1^{ij} & \dots & h_{L_c}^{ij} & 0 & 0 \\ \vdots & & & \ddots & \ddots & & \ddots & 0 \\ 0 & \dots & \dots & \dots & 0 & h_1^{ij} & \dots & h_{L_c}^{ij} \end{bmatrix} \tag{5}$$

In the above relation h_m^{ij} represents the channel filter tap for $i = 1, \dots, L_c$, L_c being the number of multipath components for the channel h_{ij} . The channels are considered to i.i.d (i.e. no two channels will have same value of $H(h_{ij})$). The values n_1 and n_2 in equation (1) and (2) represents the noise added by the signal.

III. OFDM SYSTEM

Orthogonal Frequency Division Multiplexing is a scheme which converts a serial data stream into parallel data and then processes each data stream separately [9]. The general transmitter block diagram is shown below

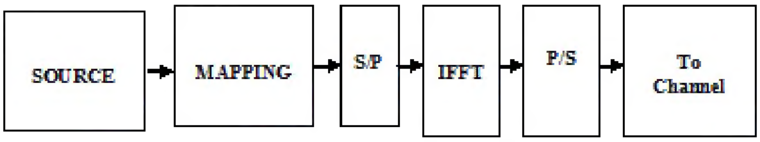

Figure 2: OFDM Transmitter

The data from the source is first subjected to the constellation mapping followed by a serial to parallel conversion block. The IFFT is taken for the mapped data which is given as

$$X(k) = \sum_{x=0}^{n-1} x(n).e^{-\frac{j2\pi nk}{N}} \tag{6}$$

Where k=0, …, N-1. After the IFFT is performed the parallel data is converted back to a serial data by means of a parallel to serial converter. The following diagram depicts the receiver part.

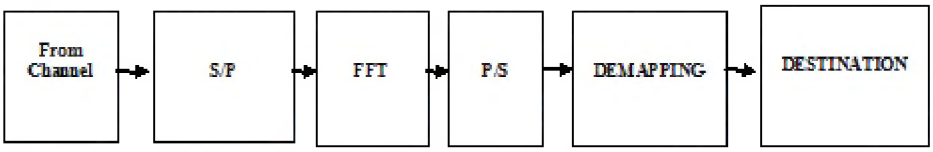

Figure 3: OFDM Receiver

The receivers performs the reverse operation of the transmitter after conversion from serial to parallel stream the FFT operation is performed on the data which is given by

$$x_n = \frac{1}{N} \sum_{x=0}^{n-1} X_k.e^{\frac{j2\pi nk}{N}} \tag{7}$$

After the FFT operation the data is then converted to serial data. The main reason for taking the IFFT is to provide a low complex means of subcarrier implementation [9].

IV. PRECODED OFDM SYSTEM

In section II the cognitive interference channel is introduced. The main motive of this work is to eliminate the interference at the primary receiver in caused by the secondary transmitter through its indirect channel h_{21}. Thus the resulting received message at the primary has to devoid of the interference given as

$$\Re_1 = H(h_{11})x_1 + n_1 \tag{8}$$

In order that the interference to be eliminated the secondary transmitter has to precode the data before transmission. The precoding is generally done with a value which is the root to the channel Toeplitz matrix [5]. Such precoding efficiently cancels out the interference but has a serious drawback of requiring a complex equalizer structure at the secondary receiver. In order to overcome this drawback the property of IFFT given below is exploited.

$$F^{-1}(x(n))|_{x(n)=x\left(n+\frac{N}{2}\right)} => X(2k) = 0 \tag{9}$$

The output of the IFFT is zero for every even position if the input is given as a cyclic repeat of the first $\frac{N}{2}$ samples. Hence the zeroed output can be used to precode the sequence of data which can be easily decoded at the secondary structure by knowing the operating mode of the transmitter through its frame.

The channel matrix is provided from the channel state information known by the secondary transmitter about its indirect channel h_{21}. The roots of the channel can synthesized by means of matrix solving algorithm such as the Gauss elimination or Gauss-Jordan method.

V. PRECODED OFDM TRANSMITTER BLOCK

The following block diagram depicts the operation of transmitter.

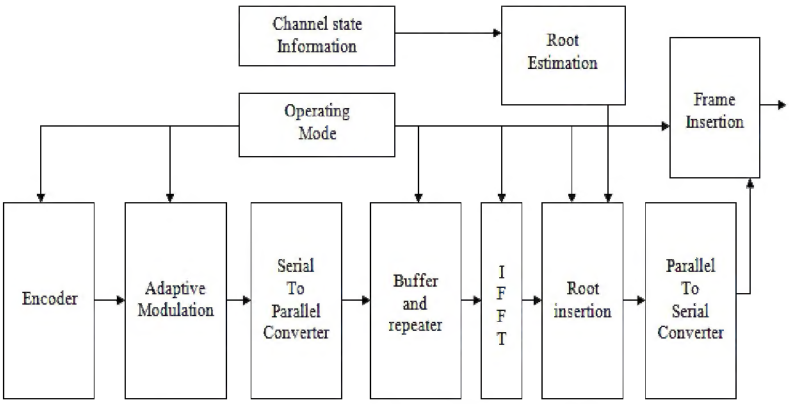

Figure 4: Precoded OFDM Transmitter

The first block is the encoder which will be discussed in the further section. The encoded data are subjected to adaptive modulation scheme in order to compensate the data rate reduction because of precoding. After the conversion of serial to parallel, based on the operating mode of the system the data are buffered and then inverse fourier transformed. Based on the channel state information available the roots are estimated such that the data when propagated through their indirect channel becomes zero. After the addition of the root values, an additional frame bits are added from which the operating mode can be conveyed to the secondary receiver.

VI. PRECODED RECEIVER BLOCK

The following diagram depicts the precoded OFDM receiver scheme.

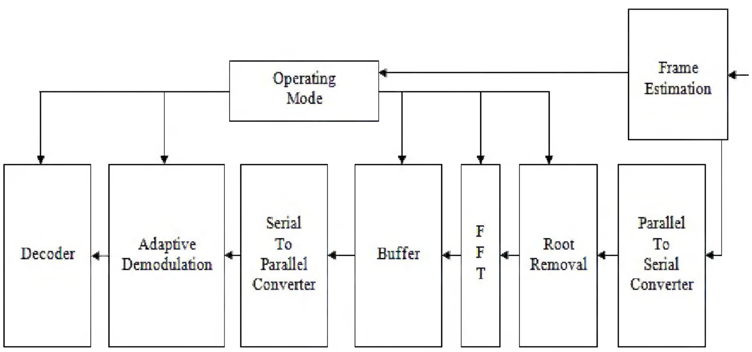

Figure 5: Precoded OFDM Receiver

The received message is first subjected to frame estimation where the operating mode of the system is estimated. Based on the operating mode received the even placed of data are removed or kept as it is. After the operation of FFT in case the operating mode is based on secondary then the buffer stores the data and waits until the next cycle is received. Then after progation from parallel to serial block the adaptive demodulation is carried out. The message is then decoded inorder to retrieve the original message signal.

The figure below depicts the frame field for transmission.

DATA	MODE	EXT

Figure 6: Frame Format

The frame consists of the data followed by mode field which specifies the current operating mode of the transmitter. The EXT field consist of additional information which is necessary for transfer control.

VII. LDPC ENCODING

The precoded OFDM system eliminates the phenomenon of interference but there is a significant increase in BER due to the noise added by the channel. To overcome this problem LDPC encoding scheme is proposed in this paper. Low density parity check codes (LDPC) were proposed in [11] with an iterative encoding scheme. LDPC codes are found to achieve closer limits to Shannon capacity. They are linear block codes with their parity matrix having a lesser number of 1's. an example parity chech matrix is given below.

$$H = \begin{bmatrix} 0 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 1 & 1 & 0 \end{bmatrix}$$

Any such matrix must be converted to an echelon form given below

$$H = \left[-P^T \mid I_{n-k} \right]$$

The encoding is done by using the generator matrix G which is based on parity P and identity matrix I

$$G = \left[I_k \mid P \right]$$

The decoding is based on soft decision decoding using the H matrix.

VII. RESULTS AND DISCUSSIONS

In this section we analyse the performance of the precoded OFDM system and the LDPC coded precoding system.

The following figure shows that the BER at the primary is reduced by precoding the message from the primary system. But there is an increase in the BER due the process of using an adaptive modulation technique. The results are simulated using MATLAB and is shown below

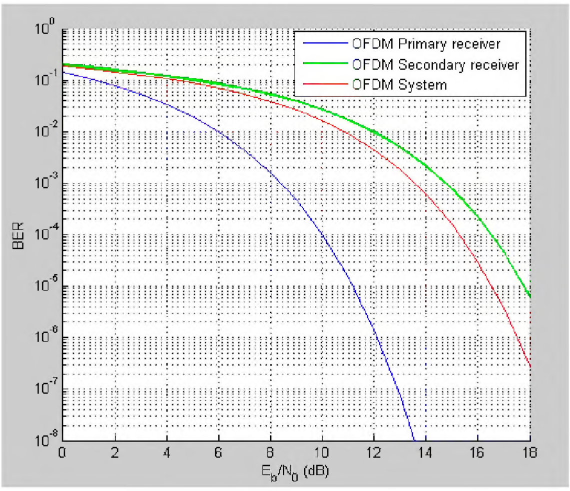

Figure 7: BER Reduction by Precoding

The graph below shows the OFDM which has its interference similar to that of the secondary system. The analysis is considered as it is considered to be most affected and posses the maximum BER.

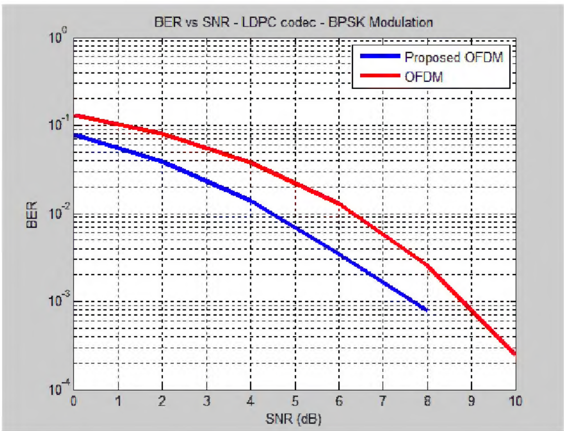

Figure 8: BER Analysis of LDPC OFDM System

The LDPC coded precoded secondary system is also depicted which shows that there is a significant reduction in the BER of the system.

VIII. CONCLUSIONS AND FUTURE WORK

The OFDM system with precoding is found to obliterate the phenomenon of interference efficiently at the primary receiver without knowing the primary message. Also the adaptive modulation is found to compensate for the reduction in data rate as a result of precoding. The LDPC encoding scheme proposed is found to suppress the effect of noise added by the channel.

Future works include the design for PAPR reduction of the system and further BER reduction at the secondary receiver proves to be vital.

REFERENCES

1. Simon Haykin, “Cognitive Radio: Brain-Empowered Wireless Communication”, IEEE Journal on Selected area in communication, Vol. 23, No. 2, February 2005

2. P. Kolodzy et al., “Next Generation Communications: Kickoff meeting”, in Proc. DARPA, Oct. 17, 2001.
3. N. Devroye, P. Mitran, and V. Tarokh. Achievable rates in cognitive radio channels. IEEE Trans. on Inform. Theory, 52(5):1813–1827, 2006.
4. Andreas F. Molisch, “Wireless Communications”, Second edition, Wiley,2011
5. Leornado S. Cardoso, Mari Kobhayashi and Merouane Debbah, “Vondermonde Frequency Division Multiplexing for Cognitive Radio,” arXiv:0803.0875v1 [cs. IT], March 2008
6. Leornado S. Cardoso, Fransico R.P. Cavalcanti, Mari Kobayashi and Merouane Debbah “Vondermonde-subspace Frequency Division Multiplexing receiver analysis,” PIMRC ,2010 IEEE 21 international Symposium on Istanbul: Turkey
7. Marco Maso, Leornado S. Cardoso, Ejder Bastug, Nguyen Linh-Trung, Merouane Debbah and ozgur Ozdemir, “On the Practical Implementation of VFDM Based Oppurtunistic Systems: Issues and Challenges”, REV journal on Electronics and Communication , Vol.2, No. 1-2, January-June, 2012
8. Simin Bokharaiee, Ha H. Nguyen and Ed Shwedyk, “Blind Spectrum Sensing for OFDM –Based Cognitive Radio System, IEEE Transaction on vehicular technology, VOL. 60,No. 3,March 2011
9. Tevfiq Yucek and Huseyin Arslan, “A Survey of Spectrum Sensing algorithms for Cognitive Radio Applications”, International Communications Surveys and Tutorials, Vol. 11 No.1, First Quarter 2009.
10. I. A. Ibragimov and O. Zeitouni. “On roots of random polynomials”. *Trans. American, Math. Soc. 349, 2427-2441*, 1997.
11. R. Gallager, 1962. “Low-density parity-check codes”. IRE Trans. Information Theory.
12. P. Jagatheeshwari, M. Rajaram, “Performance comparison of LDPC codes and turbo codes”, European jounal of scientific research, ISSN 1450-216X, vol.54, no.3, 2011.